

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of)	
)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Services)	GN Docket No. 14-177
)	
Establishing a More Flexible Framework to Facilitate Satellite)	
Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands)	IB Docket No. 15-256
)	
Petition for Rulemaking of the Fixed Wireless Communications)	
Coalition to Create Service Rules for the 42-43.5 GHz Band)	
)	RM-11664
Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 To)	
Establish Uniform License Renewal, Discontinuance of)	
Operation, and Geographic Partitioning and Spectrum)	
Disaggregation Rules and Policies for Certain Wireless Radio)	WT Docket No. 10-112
Services)	
)	
Allocation and Designation of Spectrum for Fixed-Satellite)	
Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz)	
Frequency Bands; Allocation of Spectrum to Upgrade Fixed and)	
Mobile Allocations in the 40.5-42.5 GHz Frequency Band;)	
Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for)	IB Docket No. 97-95
Wireless Services; and Allocation of Spectrum in the 37.0-38.0)	
GHz and 40.0-40.5 GHz for Government Operations)	

REPLY COMMENT OF INTEL CORPORATION

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I. Introduction and summary

Intel Corporation (“Intel”) respectfully submits this Reply Comment in the Commission’s proceeding on the use of spectrum bands above 24 GHz for mobile radio services. Intel is a leader in designing and building the essential technologies that serve as the foundation for the world's computing and communications devices. We strongly back the Commission’s efforts to make millimeter wave spectrum available for terrestrial mobile (5G) use expeditiously and flexibly.

In transitioning from the NOI to the NPRM, the Commission chose to reduce the focus to a core set of four bands (28 GHz, 37 GHz, 39 GHz, and 64-71 GHz).¹ Intel believes this focus will help expedite introduction of millimeter wave (mmW) products and services to the market, and is an important foundation for U.S. 5G leadership. As Chairman Wheeler has noted, this NPRM is “step one” and the intent is to “close this rulemaking by the summer.”² Intel also appreciates the Chairman’s intention, as the next step, to “open a new rulemaking on additional spectrum up in the higher bands.”³ Further, Intel shares Commissioner Rosenworcel’s sense of urgency that “the race to 5G is on and the United States should lead the way.”⁴ Expeditious completion of this rulemaking with straightforward operational rules that incentivize investment by industry is key to realizing these goals.

¹ *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, et al.*, Notice of Proposed Rulemaking, GN Docket No. 14-177, Released Oct 23, 2015, at 10 (“mmW NPRM”)

² Testimony of FCC Chairman Tom Wheeler, House E&C Subcommittee on Communications and Technology, FCC Oversight Hearing, Transcript at 89, Nov. 17, 2015 (“Wheeler Testimony”) available at: <http://docs.house.gov/meetings/IF/IF16/20151117/104195/HHRG-114-IF16-Transcript-20151117.pdf>.

³ See Wheeler Testimony at 89.

⁴ Testimony of FCC Commissioner Jessica Rosenworcel, House E&C Subcommittee on Communications and Technology, FCC Oversight Hearing, Transcript at 88, Nov. 17, 2015.

The mmW NPRM has resulted in a robust comment record with over fifty commenting parties submitting over one thousand total pages of non-trivial observations, opinions, and analysis. While many commenters focused on just a few issues of particular relevance to their interests, the overall coverage of the questions raised in the NPRM was thorough. Most of the key Commission proposals were addressed by at least a quarter of the commenting parties, with some issues receiving attention from nearly half the commenters. In general, commenters coalesced around clear majority positions on key issues.

In brief, Intel agrees with the majority of commenters on the key policy issues: terrestrial incumbents should be granted mobile rights; unassigned licenses should be auctioned; BTA and EA license areas should be retained; the 37 GHz band should be exclusively licensed; market-based FSS status upgrades are reasonable; the 64-71 GHz band should be unlicensed. We also offer our analysis of potential licensing and auctioning scenarios for the currently-fragmented 39 GHz band in a later section, as well as technical rules analysis in Appendix A.

While many of the Commission's primary proposals were supported by a majority of commenters, a small minority of those proposals received substantial opposition. These include: the use of a hybrid sharing scheme in the 37 GHz band; the proposal for county-based license areas; the use-it-or-share it proposal; and the proposed universal performance metric. Intel stands with the majority in opposing these proposals.

Some of these proposals are outgrowths from experimental proposals in other Commission proceedings, where the original experiments are still in the development stage. Intel respectfully submits that the additional uncertainty brought by those proposals would unnecessarily hamper the post-rulemaking development phase and could ultimately impede sustained U.S. investment in mmW 5G. Accordingly, we caution that the advantage gained from the Commission's expeditious action could be eroded if the rules contain implementation complexity that is not essential to mmW 5G. Implementing the hybrid plan experiment and the use-it-or-share-it experiment are not essential to mmW 5G, and should be re-targeted to other proceedings, other bands.

Regarding additional NPRM proposals related to licensed spectrum, Intel agrees with the majority of commenters in supporting the extension of secondary market leasing, partitioning, swaps, and aggregation/disaggregation to the mmW bands. We also agree with the majority in supporting a 10-year term for licenses including renewal expectancy, and in supporting duplexing flexibility. In the 60 GHz band, we support permitting usage aboard aircraft and support the removal of the coordination channel.

II. Recommendations specific to the 28 and 39 GHz bands

A. Fixed terrestrial incumbents should be granted mobile rights to the 28 and 39 GHz bands.

A substantial majority of commenters agree with this key proposal by the Commission to grant mobile rights to 28 and 39 GHz terrestrial incumbents.⁵ Among the few dissenting views, some satellite interests would prefer that the Commission not allow terrestrial mobile operations in these bands⁶, and one party proposed dedicated unlicensed use for most of the 28 GHz band.⁷

Intel continues to believe the Commission's proposal to grant mobile rights to terrestrial incumbents who currently hold fixed, exclusive licenses is consistent with precedent, licensee expectations, and expeditious market development. We believe it will lead to the most productive market outcome and the swiftest means of completing this NPRM.

⁵ NPRM comments of: XO Communications at 8, Verizon at 2, Mobile Future at 10, Straight Path at 14, Skyriver at 3, Qualcomm at 10, Samsung at 11, PCIA—The Wireless Infrastructure Association at 8, Nokia/Alcatel-Lucent at 15, Telecommunications Industry Association at 15, 4G-Americas at 3, Ericsson at 5, CTIA at 14, Cisco at 4, Echostar/ESOC et al. at 14, T-Mobile at 9, Consumer Technology Association at 10, Fibertower at 2, Huawei at 11, High Tech Spectrum Coalition at 4, Intel at 3.

⁶ NPRM comments of: O3b at 16, Avanti at 5.

⁷ NPRM comments of Microsoft at 17.

B. Unassigned licenses should be auctioned; the alternative proposal for overlay rights has no support in the record.

Among those parties supporting the Commission's proposal to grant mobile rights to existing incumbents, there was unanimous support for auctioning the unassigned licenses.⁸ There was no record support for the alternative proposal of using an overlay rights auction, with all commenting parties opposed to it.⁹ Commenters noted similar concerns with the overlay rights alternative, regarding difficult interference mitigation and coordination across separate mobile and fixed licensees. As we explained in our comments to the NPRM, we support the grant of mobile rights and the auctioning of unassigned licenses, and we oppose the overlay alternative due to its aforementioned disadvantages and no apparent advantages.¹⁰

C. Geographic areas should be licensed using BTAs for 28GHz and EAs for 39 and 37 GHz.

While the Commission proposed county-size license areas, the majority of commenters on this issue favor maintaining the current license geographic size for the 28 and 39 GHz bands (BTAs and EAs, respectively).¹¹ With nearly 500 BTAs available for the 28 GHz band, and 176 EAs for the 39 GHz band (and presumptively for an exclusively licensed 37 GHz band as well), geographic size variation already exists, with further variation via license partitioning and disaggregation rules. The reasons the Commission originally chose EAs and BTAs in these

⁸ NPRM comments of: XO Communications at 18, Verizon at 3, Straight Path at 16, Qualcomm at 6, Nokia/Alcatel-Lucent at 15, Ericsson at 6, Cisco at 5, Echostar/ESOC et al. at 32, T-Mobile at 9, Intel at 4.

⁹ NPRM comments of XO Communications at 17, Verizon at 3, Straight Path at 14, Skyriver at 5, Qualcomm at 7, Nokia/Alcatel-Lucent at 15, 4G-Americas at 4, Echostar/ESOC et al. at 15, T-Mobile at 9, Huawei at 11, Intel at 4.

¹⁰ NPRM comments of Intel at 7.

¹¹ NPRM comments of AT&T at 18, XO Communications at 8, Verizon at 10, Fixed Wireless Communications Coalition at 5, Mobile Future at 13, Straight Path at 17, Skyriver at 7, Qualcomm at 7, Nokia/Alcatel-Lucent at 18, Telecommunications Industry Association at 22, 4G-Americas at 6, Ericsson at 9, Cisco at 11, Consumer Technology Association at 11, Intel at 8.

bands, as opposed to smaller geographic areas (which were also considered), were detailed in our comments,¹² and remain just as valid today. The Commission should stay the course.

As noted in our comments, the Commission should not consider the geographic license size question in isolation. License partitioning and disaggregation, as well as the number of licenses created, also play a role in providing a wide range of opportunities and competitive offerings. Intel and numerous other parties including the Commission itself¹³ have made the case that combining these larger licenses with partitioning and disaggregation provides sufficient license variety to satisfy statutory obligations.

Hypothetical concerns about BTAs and EAs not being usable for smaller companies are addressed by having the ability to partition and disaggregate licenses, and are debunked in practice. As Skyriver—a small operator in the mmW bands—notes, “ EAs and BTAs have proven to be small enough that smaller companies like Skyriver who lack the resources of the larger carriers can nonetheless acquire spectrum, provide the services that the public demands, and satisfy reasonable performance requirements.”¹⁴

Other commenters preferred even smaller license geographic size, ranging from census blocks down to user-defined site licenses.¹⁵ While spectrum allocation proceedings often generate a wide range of viewpoints regarding geographic license area size, it is impossible to satisfy all opinions. Given the high transaction cost in aggregating spectrum, keeping BTA and EA licenses (if combined with partitioning and disaggregation) represents the approach most likely to produce efficient outcomes. This is especially so given the limited

¹² NPRM comments of Intel at 9.

¹³ *In the Matter of Amendment of the Commission's Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands; Implementation of Section 309(j) of the Communications Act Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands*, Report and Order and Second Notice of Proposed Rulemaking, ET Docket No. 95-183, Released November 3, 1997, at 71.

¹⁴ NPRM comments of Skyriver at 8.

¹⁵ See e.g. NPRM comments of: Open Technology Institute & Public Knowledge at 12, O3b at 28.

number of geographic area sizes to choose from, and the order-of-magnitude increase in number of geographic areas when dropping below BTA-sized partitions.

D. A market-based approach to FSS status upgrades is reasonable.

Related to the license geographic size question is the Commission's proposal for a market-based mechanism to allow FSS operators to *de facto* upgrade their status to co-primary, which many commenters supported.¹⁶ Satellite interests, on the other hand, expressed concerns about their ability or justification for acquiring licenses via auction that are larger than the relatively small protection zones they generally need,¹⁷ and/or their ability to win a competitive auction against mobile interests.¹⁸ These objections are misplaced. First, regardless of auction outcomes, there is no reason to suspect that FSS licensees could not negotiate successfully with existing or future licensees, if that were efficient. Indeed, given that existing licensees cover approximately 70 percent of U.S. POPs at 28 GHz, negotiations with existing licensees will be the rule rather than the exception in much of the country. Moreover, if FSS licensees are prepared to purchase market-based access, there are mechanisms that they could support such as partitioning licenses pre-auction or buying access at prices based on the relevant *pro rata* costs of the winning auction bids. These approaches would encourage FSS operators to efficiently size any protection zones since they would face the opportunity cost of foreclosing 5G use.

¹⁶ NPRM comments of: Telecommunications Industry Association at 11, XO Communications at 34, Nokia/Alcatel-Lucent at 24, Ericsson at 20, Cisco at 6, T-Mobile at 16, Consumer Technology Association at 16, Verizon at 22, Mobile Future at 14, Samsung at 22, Intel at 5.

¹⁷ "[T]he operation of the earth station would not adversely affect any 5G receiver located outside an irregularly-shaped compatibility zone that typically would be less than about 160 meters at its maximum distance," NPRM comments of ViaSat at 13; "[T]he required coordination distance between a transmitting gateway and a mobile base station in this band would be approximately 170 meters," NPRM comments of Echostar/ESOC et al. at 16.

¹⁸ "[T]he FSS operator would be required to bid for vastly more spectrum rights than it actually needs...an mmW auction model in which FSS operators compete with mobile operators for geographic blocks would always strongly favor the mobile bidders," NPRM comments of O3b at 18.

Satellite interests also question whether and how performance requirements would be associated with the acquisition of a terrestrial license by an FSS licensee. However, if the terrestrial obligation is reasonably set, it need not be onerous for the FSS licensee to meet the obligation itself, or disaggregate to someone who can. In that regard, the general consensus in the comment record is that performance requirements for terrestrial mobile licensees should be flexible and tailored to the wide range of potential 5G services offered.¹⁹

E. Lack of WRC-2015 consideration of the 28 GHz band should not impact moving forward with mobile 5G services the band.

As a result of the WRC-15, the 28 GHz band was excluded from the list of bands being considered for study towards WRC-19 Agenda Item 1.13. Satellite interests argue that this exclusion means the 28 GHz band should be dropped from consideration by the NPRM.²⁰ While the WRC-15 exclusion was disappointing, Intel agrees with the Telecommunications Industry Association that “the Commission should reject any suggestion that the failure of WRC-15 to agree to the 28 GHz band as a candidate band for International Mobile Telecommunications (“IMT”) should preclude the United States from moving forward with fully implementing the existing global Fixed and Mobile allocations.”²¹ Several other commenters echo these sentiments²² and Chairman Wheeler notably said, “It would have been far better if the [WRC-15] had agreed to study the 28 GHz band...but the U.S. and other leaders in the 5G arena will go forward with our own studies. And I am fully confident that, as we and others move forward with 28 GHz, an international consensus will develop.”²³

¹⁹ See e.g. NPRM comments of: Telecommunications Industry Association at 27, Verizon at 19, Qualcomm at 13, Ericsson at 10, Intel at 24.

²⁰ See e.g. NPRM comments of: Global VSAT forum at 2, EMEA Satellite Operators Association at 2, Avanti Communications at 2.

²¹ NPRM comments of Telecommunications Industry Association at 15.

²² See e.g. NPRM comments of: Microsoft at 3, Cisco at 4, Samsung at 10, Nokia/Alcatel-Lucent at 10, XO Communications at 3.

²³ Statement of FCC Chairman Wheeler (December 17, 2015) available at: http://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db1217/DOC-336917A1.pdf

Major markets like the U.S., Japan, and Korea are moving expeditiously, blazing the trail for mobile 5G services in the 28 GHz band, in spite of the WRC-2015 decision not to study the 28 GHz band leading up to WRC-19. With respect to the 28 GHz band, while Intel believes harmonized bands are important, especially in driving costs down in the early market, the mobile industry could create tuning ranges that potentially cover WRC-19 Agenda Item 1.13 ranges directly below 28 GHz. In this way, a single radio could cover various regions of the world, increasing economies of scale. An example where this occurred in the past is in the early days of IMT-2000 (3G) where the larger range of 1710-2025 MHz was identified for IMT in the Radio Regulations in order to account for different portions of that range being available in different countries. Furthermore, Intel notes that the 37-40 GHz band is a subject of this NPRM (as the “37 GHz” and “39 GHz” bands), and is included in the bands to be studied under WRC-19 Agenda Item 1.13. This helps facilitate possible global harmonization.

F. License size for 39 GHz should reflect information on the current fragmented state of the band.

Commenters note several large block size preferences for the 39 GHz band, with a minimum of 200 MHz as the most frequently proposed size.²⁴ Two incumbent licensees expressed a preference for maintaining the current paired 50 MHz band plan in 39 GHz.²⁵ Two other parties, including an incumbent licensee, preferred larger licenses of 400-500 MHz for the band.²⁶

Intel continues to believe that pre-auction voluntary license swaps of the existing 50 MHz licenses (importantly, including the unassigned licenses held by the Commission,²⁷ and allowing pair-splitting) will likely

²⁴ NPRM comments of: AT&T at 14, Verizon at 7, Qualcomm at 11, Samsung at 14, TIA at 29, 4G-Americas at 14, Ericsson at 8, CTIA at 22.

²⁵ NPRM comments of: XO Communications at 24, FiberTower at 6.

²⁶ NPRM comments of: Straight Path at 23, Nokia at 20.

²⁷ Commission-held unassigned licenses represent nearly 65% of all available 39 GHz fixed terrestrial licenses, while Straight Path, as the largest incumbent holder of active licenses by a significant margin, holds nearly 34% of all available licenses.

facilitate the creation of more contiguous spectrum in the 39 GHz band. To illustrate this point, Intel analyzed the current structure of active 39 GHz fixed terrestrial licenses in the 65 largest EA markets by population (the top 65 EAs represent 81% of the population²⁸), and we include a summary chart of the results in Figure A below, titled “39 GHz Current Active Licenses.”

In that figure, all active fixed-terrestrial licenses are color-coded according to licensee, and placed into their channel locations (vertical axis) versus EA market location (horizontal axis, with the top 65 EAs ranked by population). Unassigned licenses held by the FCC are shown as white squares in the matrix.

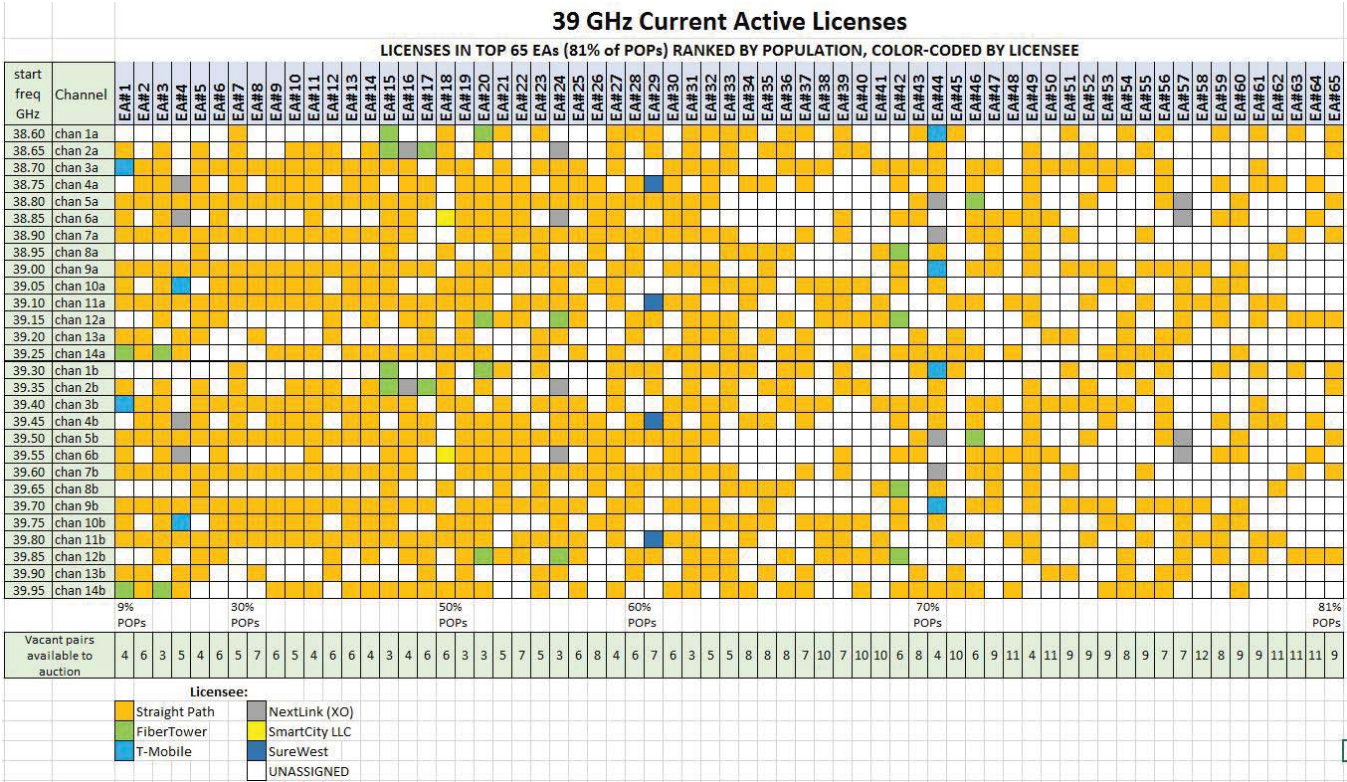


Figure A. 39 GHz license map, showing all assigned and unassigned licenses by licensee, in the top 65 EA markets.

²⁸ Per 2000 census data. Downloaded from: http://wireless.fcc.gov/auctions/data/maps/cntysv2000_census.xls

Currently, fragmentation abounds, both within and across all EAs. The jumble of unassigned licenses mixed with scattered patches of active licenses (overwhelmingly held by one incumbent) illustrates graphically the potential benefit from allowing pre-auction license swaps in each EA. Note also that since the current channel plan consists of paired licenses, the bottom 14 channels in the matrix diagram are a replica of the top 14 channels.

Holding an auction based on this current fragmented state of licenses in the band would likely be inefficient and depress bidding, since bidders would reasonably expect to incur significant transaction costs in assembling contiguous spectrum post-auction. While Figure A demonstrates that there is potential value in conducting pre-auction license swaps, there are a number of different ways the swaps could be structured, depending on participation level and assumptions on the band.

In Figure B, titled “Scenario 1” Intel illustrates a hypothetical “best case” swap where maximizing contiguous spectrum for fixed incumbents, and contiguous spectrum for new entrants adjacent to the 37 GHz band, are the main goals. In creating “Scenario 1,” all licenses from the “39 GHz Current Active Licenses” graphic are swapped within each EA to create contiguous frequency clusters, relative to 40 GHz at the top of the band (the bottom in the figure). In effect, this multi-party license swap results in an efficient repacking, but without the overhead associated with a more traditional repacking process. Both the unassigned and the assigned licenses are consolidated, benefitting both incumbents and new entrants, assuming larger contiguous licenses are preferable to all. In that case, the existing licensees and the FCC should have ample opportunity to engage in “win/win” swaps.

Under “Scenario 1” a *minimum* of 300 MHz of contiguous spectrum would be available for new entrants in all of the top 65 EA markets, and that spectrum is adjacent to the 37 GHz band under this scenario. An average of 510 MHz of contiguous spectrum is made available to bidders in the top 30 markets, and an average

of 820 MHz is made available in markets 31-65. That average would likely be still larger in the 111 remaining smaller EA markets (not shown in the figure).

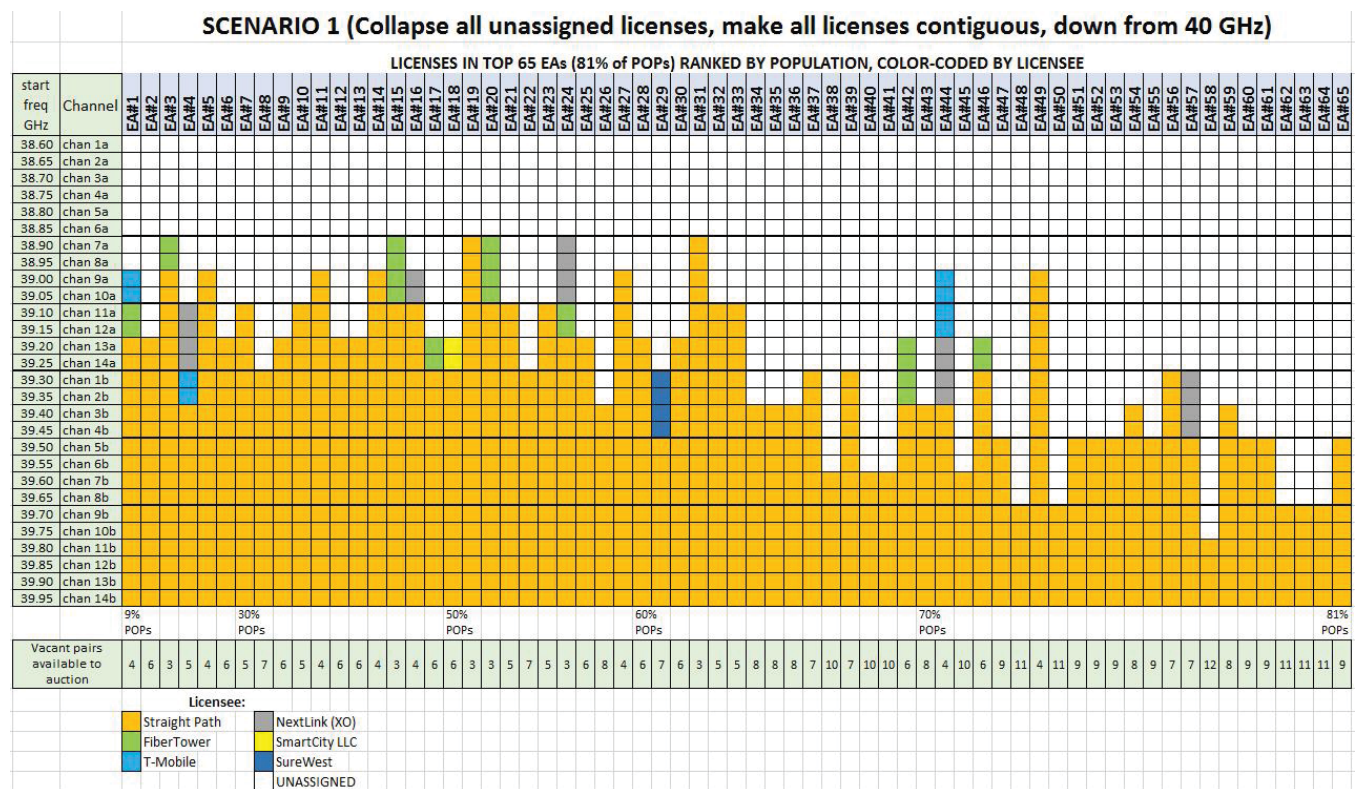


Figure B. “Scenario 1” where licenses are swapped pre-auction to maximize contiguous spectrum with the adjacent 37 GHz band.

However, the Figure B “Scenario 1” must be caveated. First, since license swaps would be voluntary and not all licensees may choose to participate, this graphic is likely too optimistic. Further, the potential issue of impairments due to future DoD/NASA deployment in the 39.5-40 GHz segment²⁹ is presumed to be resolved prior to the auction, making the 39.5-40 GHz segment “relatively fungible” with the rest of the 39 GHz band, and

²⁹ mmW NPRM ¶¶37, 46

requiring no special partitioning. Finally, any impact due to RSA licenses is not accounted for in the graphic.³⁰ Thus, “Scenario 1” probably represents the best case.

Nonetheless, it illustrates that in comparison to the status-quo case in Figure A, pre-auction swaps are likely to greatly reduce license fragmentation.

Indeed, if only the FCC and Straight Path (the only fixed incumbent currently on record as supporting a pre-auction swap process,³¹) engaged in swaps, significant improvement in the amount of contiguous spectrum available would still be achievable. This result is demonstrated in the next figure (Figure C: “Scenario 2”), where all incumbent licensees except Straight Path remain in their original channel positions. The swap under “Scenario 2” is thus limited to the unassigned licenses held by the Commission and the active licenses held by Straight Path.

While fragments still exist, “Scenario 2” in Figure C shows vast improvement in contiguous spectrum compared to the status-quo in Figure A. Note the “Scenario 2” matrix shows the boundaries for an illustrative 200 MHz band plan (red horizontal lines). 5G Licenses larger than 200 MHz would likely result in more encumbrances per license at auction, particularly if the remainder of fixed terrestrial incumbents do not engage in the pre-auction swap process. A license size smaller than 200 MHz is not supported by most commenters and would be inconsistent with the generally large bandwidth requirements for many mmW 5G services.

³⁰ The RSA licenses are in the CF (common carrier fixed point-to-point microwave) category in the FCC’s ULS database. As of early February 2016, there are 231 active licenses, with Straight Path holding 103. These licenses have self-defined service areas and do not necessarily align with EA or other standard geographic license boundaries.

³¹ NPRM comments of Straight Path at 25.

III. Recommendations specific to the 37 GHz band

A. The hybrid sharing proposal should not be pursued in 37 GHz, and the band should instead be exclusively licensed.

A substantial majority of commenting parties opposed the NPRM proposal of a hybrid plan for the 37 GHz band.³² The comment record contains a comprehensive collection of reasons why the hybrid plan is ill-conceived and unwise for this band. The opposing parties proposed multiple alternatives, with exclusive licensing as the dominant recommendation. Some opponents of the hybrid plan prefer unlicensed use of the band. Regardless, all agree that an experiment like the hybrid plan is inappropriate in this key spectrum band. The myriad unresolved issues and ill-defined constraints could severely limit the viability of the band.

Intel continues to recommend that the hybrid approach not be pursued for the 37 GHz band.³³ The four mmW bands targeted in this NPRM should provide an important foundation for U.S. 5G leadership, and the hybrid plan for 37 GHz would undermine part of that foundation, adding unjustifiable delays and additional uncertainty. While there may prove to be future value in a market development effort for the hybrid plan's shared industrial/enterprise user-class, that effort should be targeted in a different band.

Significantly, the 37 GHz band has no incumbent non-Federal operations, and as an exclusively licensed band, it would likely receive strong industry support for mmW product and service development. On the other hand, the market potential and return-on-investment of the 37 GHz band under the hybrid proposal is at best

³² NPRM comments of: Mobile Future at 11, Ericsson at 7, AT&T at 15, Qualcomm at 9, PCIA—The Wireless Infrastructure Association at 10, Nokia/Alcatel-Lucent at 16, Samsung at 13, Telecommunications Industry Association at 18, Verizon at 7, CTIA at 15, T-Mobile at 12, Consumer Technology Association at 10, National Cable & Telecommunications Association at 13, High Tech Spectrum Coalition at 5, Intel at 13.

³³ In our comments, Intel elaborated in detail on the issues we see with the hybrid plan. To summarize those issues, the potential market size and growth of the proposed user class is unquantified; bandwidth and other user requirements are undefined; the necessary interest from the vendor ecosystem to develop products, services, and standards has not been demonstrated; there is no proven, scalable sharing framework; other bands may be more ideally suited, once the aforementioned issues are better defined. NPRM comments of Intel at 13.

cloudy, and when companies and standards organizations make resource allocation and prioritization decisions, it could come up short.

Intel does not dismiss the basic development goals for this user class out of hand, and in our comments we proposed alternative bands where this experiment could be studied further, with the 3.5 GHz band as a leading candidate.³⁴ Expanding further on alternative bands, several commenters expressed a desire for the Commission to consider a future rulemaking to develop rules for the 70/80 GHz bands,³⁵ and Intel agrees with these commenters. We believe these bands could be useful for consideration of licensed sharing techniques or a license-by-rule regime, for user categories such as universities, enterprises, and industrial. This would intersect the overarching goals of the hybrid plan without impacting the critical path of developing the “core-four” mmW bands.

IV. Recommendations specific to the 64-71 GHz band

A. The 64-71 GHz band should be unlicensed, under Part 15 rules.

A majority of commenters favored the Commission’s proposal for unlicensed use of the 64-71 GHz band,³⁶ with some suggesting extending the band beyond 71 GHz. However, a noteworthy minority of

³⁴ The 3.5 GHz band not only already has the license-by-rule user class the hybrid proposal targets, but also has geographically-small exclusive licenses which would approximate the size of the enterprise/industrial facilities. Small exclusive licenses might be even more attractive than license-by-rule for certain members of this user class. Furthermore, the development of the sharing framework at 3.5 GHz is well underway (and in any case, that framework has unproven scalability to other bands, 37 GHz in particular). NPRM comments of Intel at 14.

³⁵ See e.g. NPRM comments of: Nokia/Alcatel-Lucent at 12, T-Mobile at 4, Huawei at 7.

³⁶ NPRM comments of: Boeing at 11, Wi-Fi Alliance at 5, Fixed Wireless Communications Coalition at 3, Straight Path at 6, Qualcomm at 14, Consumer Technology Association at 8, Dynamic Spectrum Alliance at 2, Facebook at 5, Google at 6, Microsoft at 5, National Cable & Telecommunications Association at 3, Open Technology Institute & Public Knowledge at 27, ViaSat at 21, Vubiq Networks at 3, Intel at 17.

commenters suggested that the 66-71 GHz portion should be exclusively licensed.³⁷ Those commenters cite the desire to align with a WRC-19 study item for the 66-76 GHz band, and to balance the quantities of licensed and unlicensed spectrum allocated via the mmW NPRM.

If the 37 GHz band becomes an exclusive licensed band as commenters recommend, then the case for licensing the 66-71 GHz band is weakened. Further, the outcome of studies leading to a possible WRC-19 decision on 66-76 GHz is uncertain. It may well be the case that by WRC-19, the use of the 64-71 GHz band in the U.S. and elsewhere, for extension of WiGig/IEEE 802.11ay, could have gained sufficient traction that unlicensed use in other geographies would merit further consideration. Such progress made in deploying and adopting unlicensed devices in the 66-71 GHz portion of the band could be a consideration in the WRC-19 deliberations.

Intel continues to favor unlicensed use for the 64-71 GHz band, under the same Part 15 rules as the 57-64 GHz band. As we noted in our comments, the 64-71 band is ideally situated to extend the growing demand for IEEE 802.11ad (WiGig®) applications; the IEEE 802 has created a new 802.11ay project to address this growth, including the nine usage models defined so far; and industry stakeholders have demonstrated strong support.³⁸ We further note in our comments, “The envisioned applications and usages identified by the IEEE task group 802.11ay require additional spectrum. The growing list of both indoor and outdoor applications calls for much higher throughputs (20 Gbps and higher) than are currently attainable in the 57-64 GHz band alone. A lesser amount of spectrum would diminish the growth potential and limit the usage cases and the simultaneous users of high bandwidth services.”³⁹

³⁷ NPRM comments of: ATT at 17, Verizon at 13, Mobile Future at 16, Nokia/Alcatel-Lucent at 17, Ericsson at 19, CTIA at 17, T-Mobile at 15.

³⁸ NPRM comments of Intel at 17.

³⁹ NPRM comments of Intel at 18.

Noting the support in the comment record,⁴⁰ Intel continues to believe the Commission should consider lifting the prohibition on use aboard aircraft in the 57-64 GHz band, and refrain from introducing such a restriction in the 64-71 GHz allocation. We anticipate the Wi-Fi Alliance will submit compatibility analysis in the record, to further the Commission's goal of studying "compatibility of operation of these new chipsets and their operation on-board inflight aircraft."⁴¹ Intel also notes there was unanimous support in the record for removing the 57.00-57.05 GHz coordination channel requirement.⁴²

Finally, Intel believes the Commission should consider updating their KDB (Knowledge Data Base) guidance for equipment authorizations of 60 GHz devices, and millimeter wave devices in general. Intel supports a broader measurement averaging area for evaluating power density, for example as recommended by TIA and the Mobile Manufacturers Forum in their NPRM comments supporting adoption of IEEE C95.1-2005 as updated by IEEE C95-1a-2010.⁴³

V. General considerations for licensed bands.

Secondary market transactions should be permitted in the mmW bands. A majority of commenters support secondary market leasing, partitioning, and aggregation/disaggregation transactions in the mmW

⁴⁰ NPRM comments of: Wi-Fi Alliance at 7, Consumer Technology Association at 8, Boeing at 11, Dynamic Spectrum Alliance at 3, Microsoft at 11, National Cable & Telecommunications Association at 7.

⁴¹ mmW NPRM ¶1306

⁴² NPRM comments of: Microsoft at 7, Wi-Fi Alliance at 9, Qualcomm at 15, National Cable & Telecommunications Association at 5, Vubiq Networks at 5, Intel at 19.

⁴³ NPRM comments of Telecommunications Industry Association at 35, Mobile Manufacturers Forum at 7.

bands.⁴⁴ Intel continues to believe that permitting all secondary market transactions, including the splitting of paired spectrum in the 39 GHz band as well as spectrum swaps, furthers the flexibility goals of this proceeding.⁴⁵

A 10-year license term with renewal expectancy is reasonable. Commenters overwhelmingly support at least a 10-year term with renewal expectancy.⁴⁶ A minority suggested shorter terms of 3-5 years.⁴⁷ Intel agrees with the majority that a 10 year term with renewal expectancy is reasonable in light of the uncertainties associated with the development of mmW products and services.⁴⁸

The use-it-or-share-it proposal is counterproductive and problematic. A majority of commenters opposed the use-it-or-share-it proposal.⁴⁹ As Verizon notes, “the stakes are too high here for such an experiment—especially given that the Commission is already proposing to employ a traditional performance requirement to achieve the goal of ensuring that operators use spectrum productively.”⁵⁰ A minority of commenters supported the proposal.⁵¹ Intel continues to believe this proposal is problematic both from a definitional and operational perspective. As we detailed in our comments,⁵² and even if one ignores the definitional issues, the proposal would be counterproductive to the intent of the performance requirements and would undercut the efficient operation of secondary markets.

⁴⁴ NPRM comments of XO Communications at 23, Verizon at 13, Qualcomm at 8, Telecommunications Industry Association at 29, Ericsson at 6, Cisco at 11, T-Mobile at 9, FiberTower at 8, Consumer Technology Association at 14, High Tech Spectrum Coalition at 5, Intel at 25.

⁴⁵ NPRM comments of Intel at 8 and 25.

⁴⁶ NPRM comments of AT&T at 20, XO Communications at 22, Verizon at 10, Mobile Future at 13, Straight Path at 38, Qualcomm at 11, PCIA—The Wireless Infrastructure Association at 11, Nokia/Alcatel-Lucent at 19, Telecommunications Industry Association at 25, CTIA at 22, High Tech Spectrum Coalition at 4, Intel at 23.

⁴⁷ See e.g. NPRM comments of: O3b at 23, Open Technology Institute at 23.

⁴⁸ NPRM comments of Intel at 23.

⁴⁹ NPRM comments of: Telecommunications Industry Association at 26, XO Communications at 29, Verizon at 20, Mobile Future at 16, Qualcomm at 14, Nokia/Alcatel-Lucent at 20, Ericsson at 8, AT&T at 20, CTIA at 26, NCTA at 10, High Tech Spectrum Coalition at 5, Intel at 20.

⁵⁰ NPRM comments of Verizon at 20.

⁵¹ NPRM comments of Federated Wireless at 20, Open Technology Institute & Public Knowledge at 11.

⁵² NPRM comments of Intel at 20.

Flexible duplexing rules should be adopted for all mmW bands. Commenters were unanimous in supporting flexible duplexing rules.⁵³ Commenters, including Intel, noted that future duplexing innovations should not be foreclosed via a specific duplexing mandate, even when considering that under the current state of technology, TDD is the only viable choice for mobile mmW implementations.

VI. Recommendations in support of technical rules for licensed bands.

Intel believes that existing rules regarding EIRP and OOB E applicable to fixed stations in the 28 and 39 GHz bands should remain unchanged. Regarding mobile services in the 28, 39, and 37 GHz bands, Intel proposes an EIRP of up to 75 dBm for base station (BS) and 43 dBm for the user equipment (UE). Our analysis in Appendix A confirms that such power levels are realistically implementable and meet throughput and range expectations.

Several factors relating to device performance affect the determination of a suitable EIRP. For example, conducted power to each antenna element directly impacts implementation complexity and cannot be easily increased beyond certain levels, e.g. 10 dBm, without paying a considerable penalty on implementation complexity. As a result, the main driver for an increase in EIRP becomes increasing the number of elements in the antenna array. However, antenna array size is also limited by the physical dimensions of the form factors considered. Taking into account our expectations for future technological improvements, EIRP levels in excess of 75 dBm for base stations and 43 dBm for UEs might not prove to be practical due to form-factor and conducted power limitations.

⁵³ NPRM comments of: Cisco at 9, FiberTower at 9, XO Communications at 24, Verizon at 17, Straight Path at 23, Skyriver at 16, Samsung at 17, Nokia/Alcatel-Lucent at 26, Telecommunications Industry Association at 31, 4G-Americas at 11, Ericsson at 9, Intel at 20.

Intel agrees with commenters proposing that technical rules should allow for a CPE class of user devices, in addition to UEs, with maximum allowed EIRP levels in between that of UEs and Base Stations.⁵⁴ Our analysis in Appendix A suggests that an EIRP of up to 55 dBm would be adequate for the CPE class of user devices.

Regarding out-of-band emissions (OOBE), while several commenters generally agreed with the Commission on specifying an OOBE level of -13 dBm/MHz, we note that one commenter recommended relaxation in the first MHz outside the block⁵⁵ and another commenter expressed intention to file further comments.⁵⁶ Intel previously expressed concern about specifying the -13 dBm/MHz level in the first 50 MHz outside the channel edge and proposed a sloped mask approach such as one adopted for WiGig systems.⁵⁷ We note no other commenter proposed such an approach. If the Commission decides to retain its step mask proposal, we note the trade-off between mask performance and power amplifier (PA) efficiency leading to reduced power consumption. Our analyses confirm that, given the status of the filter technology and its progress over time, and given energy efficiency is an important objective of 5G systems, a level of -11 dBm/MHz in the first 20 MHz outside the channel edge would be a reasonable approach that balances performance and cost. Beyond 20 MHz, the Commission's proposed value of -13 dBm/MHz seems appropriate.

VII. Conclusions

Intel supports the Commission's efforts to make millimeter wave spectrum available for terrestrial mobile (5G) use expeditiously and flexibly. We support a mix of licensed and unlicensed spectrum (28, 37, and 39 GHz licensed, 64-71 GHz unlicensed). In the mmW bands, Intel does not support the sharing-based proposals

⁵⁴ NPRM comments of: Nokia/Alcatel-Lucent at 27, Qualcomm at 16, Samsung at 19, Verizon at 17

⁵⁵ NPRM comments of Nokia/Alcatel-Lucent at 28.

⁵⁶ NPRM comments of Samsung at 19.

⁵⁷ *Ex parte* presentation of Intel Corporation, GN Docket No. 14-177, filed August 10, 2015, at 20.

such as the hybrid plan for 37 GHz and the use-it-or-share-it proposal. We believe the sharing experiments are best targeted in other bands outside these key mmW bands. In terms of licensed spectrum, we support: enabling all secondary market tools, 10-year license terms with renewal expectancy, auctioning of unassigned licenses, maintaining current geographic areas in the 28 and 39 GHz bands and EAs for the 37 GHz band, and market-based mechanisms to allow FSS operators a de-facto status upgrade. Intel also provided analysis to justify the value of pre-auction license swaps in the currently-congested 39 GHz band, as well an analysis of technical rules.

Appendix A: Technical analysis in support of technical rules

Table A1 – Basic assumptions

	QAM64 3/4	QPSK 1/2	QAM64 3/4	QPSK 1/2
Channel BW [MHz]	800	800	200	200
bits/sym	6	2	6	2
coding rate	3/4	1/2	3/4	1/2
Cyclic prefix OH [%]	7	7	7	7
Unoccupied BW [%]	10	10	10	10
Signaling OH [%]	15	15	15	15
TDD split [%]	50	50	50	50
Theoretical rate [Mbps]	3600	800	900	200
SISO UL/DL rate [Mbps]	1281	285	320	71
MIMO factor	2	2	2	2
MIMO UL/DL rate [Mbps]	2561	569	640	142

Table A2 - Sample link budget at 28 and 39 GHz for two different channel bandwidth, LOS and NLOS conditions.

		28GHz				39GHz			
		BS-->UE		UE-->BS		BS-->UE		UE-->BS	
	Carrier frequency [MHz]	28000				39000			
Rx	BW [MHz]	800.0	200.0	800.0	200.0	800.0	200.0	800.0	200.0
	NF per RF single tranceiver [dB]	8.5	8.5	6.5	6.5	9.0	9.0	7.0	7.0
	Single element KTBF [dBm]	-76.5	-82.5	-78.5	-84.5	-76.0	-82.0	-78.0	-84.0
	Antenna Array number	8	8	256	256	8	8	256	256
	Rx BF signal gain [dB]	18	18	48	48	18	18	48	48
	Rx BF noise gain [dB]	9	9	24	24	9	9	24	24
	Rx antenna element gain [dBi]	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Rx traces losses [dB]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	SNRmin in LOS for QPSK-1/2 [dB]	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	SNRmin in LOS for QAM64-3/4 [dB]	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
	SNRmin in NLOS for QPSK-1/2 [dB]	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
	SNRmin in NLOS for QAM64-3/4 [dB]	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5
	Rx sensitivity NLOS QPSK-1/2 [dBm]	-79.5	-85.5	-96.6	-102.6	-79.0	-85.0	-96.1	-102.1
	Rx sensitivity NLOS QAM64-3/4 [dBm]	-63.5	-69.5	-80.6	-86.6	-63.0	-69.0	-80.1	-86.1
Tx	Tx conductive power per element [dBm]	11.0	11.0	11.0	11.0	10.0	10.0	10.0	10.0
	Number of Tx elements	256	256	8	8	256	256	8	8
	Tx antenna element gain [dBi]	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Tx traces losses [dB]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Tx power reduction for QAM64-3/4 [dB]	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	Total EIRP for QPSK-1/2 [dBmi]	61.7	61.7	31.6	31.6	60.7	60.7	30.6	30.6
Channel	Free space path loss at 1m [dB]	61.4				64.3			
	Shadowing for NLOS only [dB]	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	PL exponent LOS	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
	PL exponent NLOS	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Coverage	NLOS distance for QPSK-1/2 [m]	113	170	47	70	84	126	35	52
	NLOS distance for QAM64-3/4 [m]	25	38	10	16	23	35	9	14
	LOS distance for QPSK-1/2 [m]	8740	16912	2089	4043	7414	14347	1772	3430
	LOS distance for QAM64-3/4 [m]	874	1691	209	404	741	1435	177	343

Figure A1 – Throughput vs range (28 GHz) for link budget in Table A2.

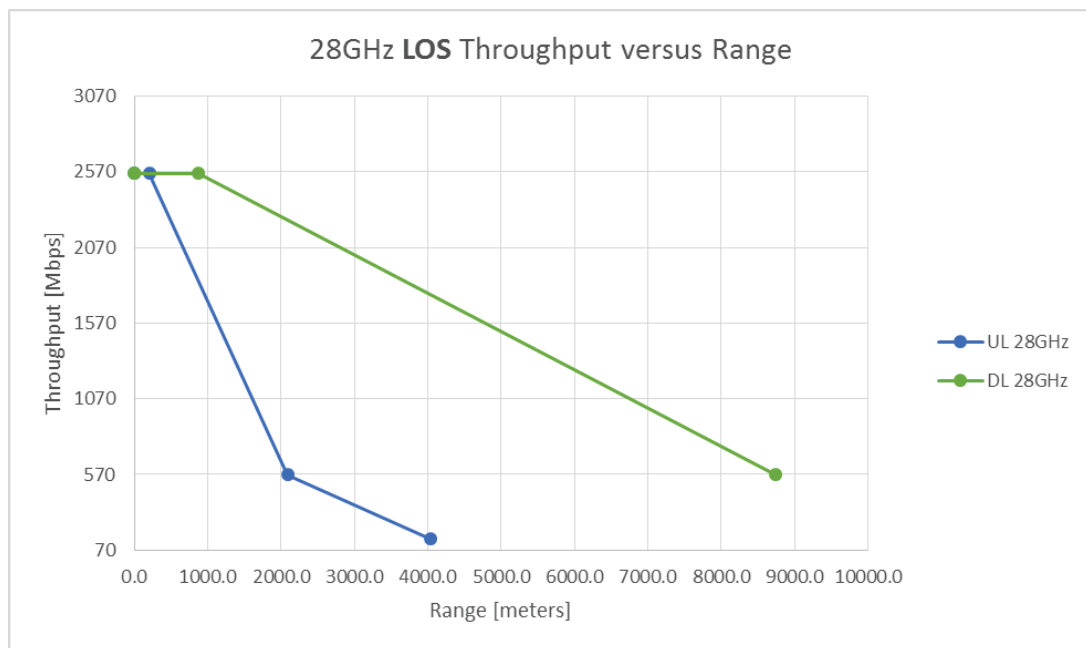
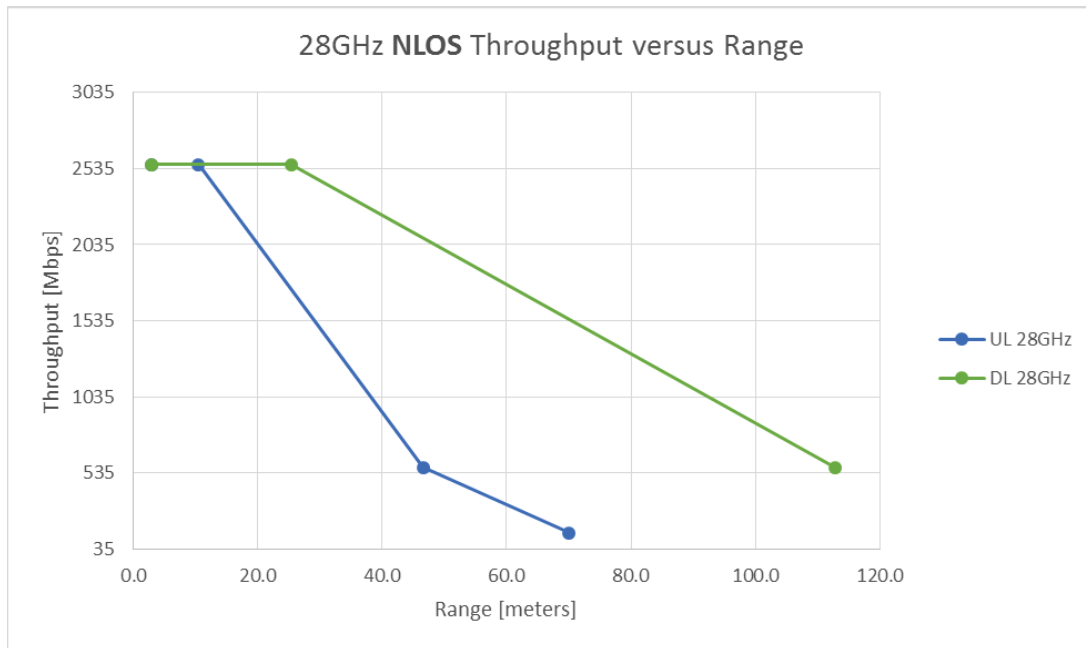


Figure A2 – Throughput vs range (39 GHz) for link budget in Table A2.

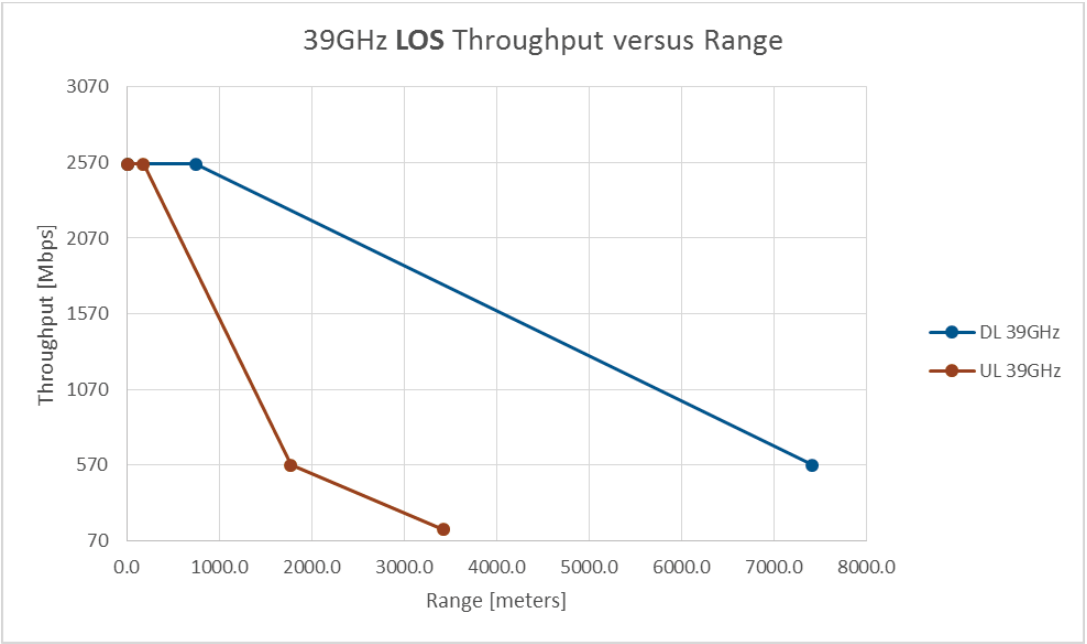
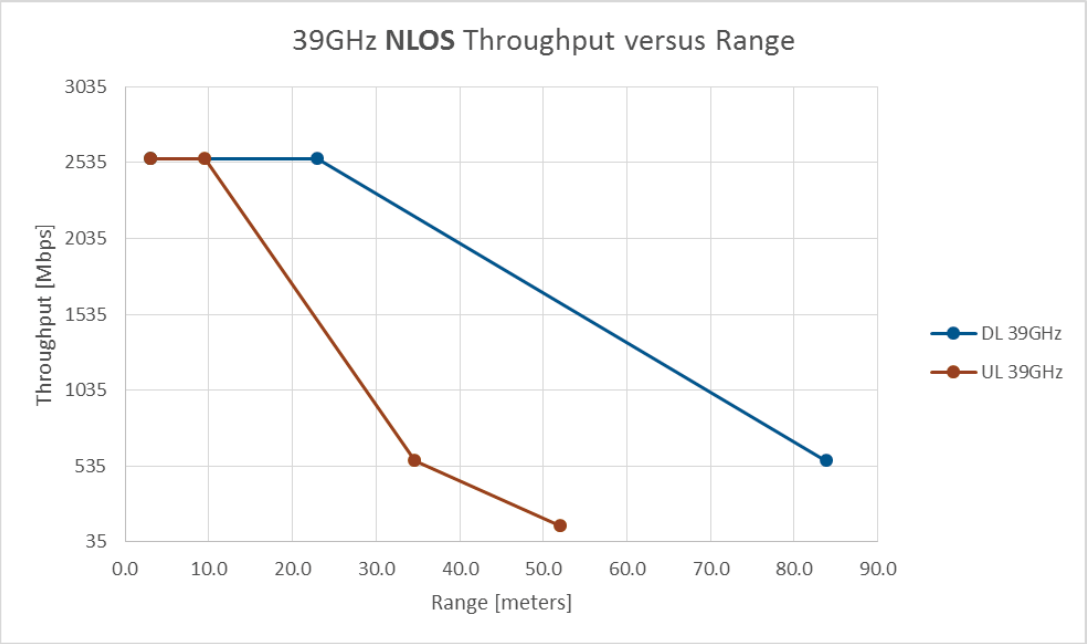


Table A3 - Sample link budget at 28 and 39 GHz for two different channel bandwidth, LOS and NLOS conditions (CPE device).

		28GHz				39GHz			
		BS-->CPE		CPE-->BS		BS-->CPE		CPE-->BS	
		Carrier frequency [MHz]							
		28000				39000			
Rx	BW [MHz]	800.0	200.0	800.0	200.0	800.0	200.0	800.0	200.0
	NF per RF single tranceiver [dB]	7.5	7.5	6.5	6.5	8.0	8.0	7.0	7.0
	Single element KTBF [dBm]	-77.5	-83.5	-78.5	-84.5	-77.0	-83.0	-78.0	-84.0
	Antenna Array number	64	64	256	256	64	64	256	256
	Rx BF signal gain [dB]	36	36	48	48	36	36	48	48
	Rx BF noise gain [dB]	18	18	24	24	18	18	24	24
	Rx antenna element gain [dBi]	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Rx traces losses [dB]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	SNRmin in LOS for QPSK-1/2 [dB]	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	SNRmin in LOS for QAM64-3/4 [dB]	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
	SNRmin in NLOS for QPSK-1/2 [dB]	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
	SNRmin in NLOS for QAM64-3/4 [dB]	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5
	Rx sensitivity NLOS QPSK-1/2 [dBm]	-89.5	-95.6	-96.6	-102.6	-89.0	-95.1	-96.1	-102.1
Rx sensitivity NLOS QAM64-3/4 [dBm]	-73.5	-79.6	-80.6	-86.6	-73.0	-79.1	-80.1	-86.1	
Tx	Tx conductive power per element [dBm]	11.0	11.0	11.0	11.0	10.0	10.0	10.0	10.0
	Number of Tx elements	256	256	64	64	256	256	64	64
	Tx antenna element gain [dBi]	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Tx traces losses [dB]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Tx power reduction for QAM64-3/4 [dB]	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	Total EIRP for QPSK-1/2 [dBmi]	61.7	61.7	49.6	49.6	60.7	60.7	48.6	48.6
Channel	Free space path loss at 1m [dB]	61.4				64.3			
	Shadowing for NLOS only [dB]	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	PL exponent LOS	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
	PL exponent NLOS	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Coverage	NLOS distance for QPSK-1/2 [m]	222	334	158	238	165	249	118	177
	NLOS distance for QAM64-3/4 [m]	50	75	36	54	45	68	32	48
	LOS distance for QPSK-1/2 [m]	26252	50800	15139	29295	22271	43096	12843	24852
	LOS distance for QAM64-3/4 [m]	2625	5080	1514	2929	2227	4310	1284	2485

Figure A3 - Throughput vs range (28 GHz) for link budget in Table A3.

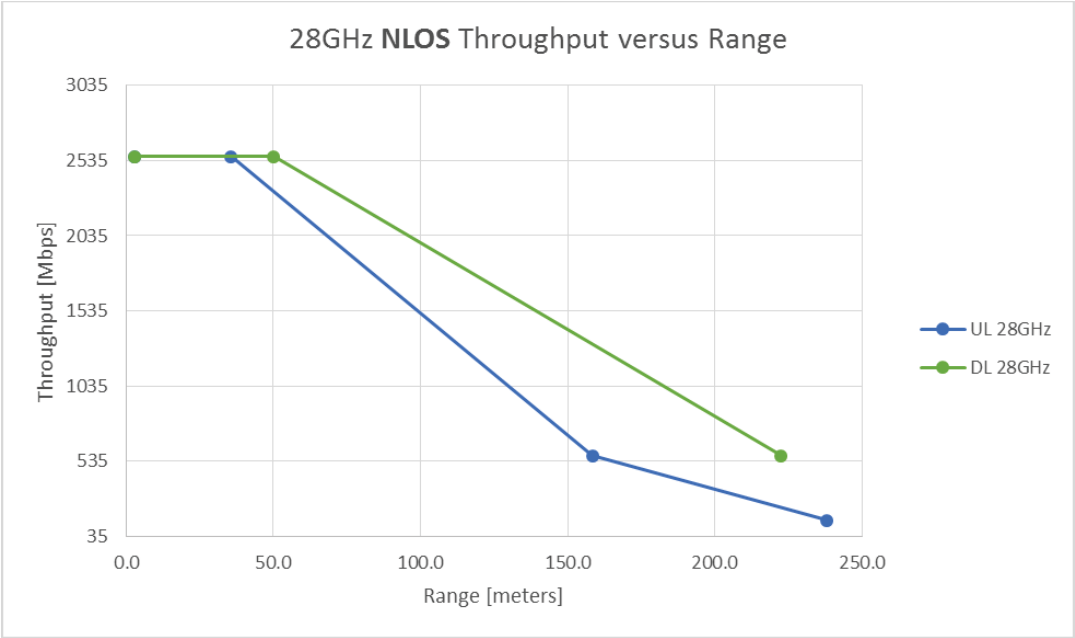


Figure A4 - Throughput vs range (39 GHz) for link budget in Table A3.

